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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,468,924**, on May 28, 2004, by **LASER DIAGNOSTIC INSTRUMENTS INTERNATIONAL INC.**, assignee of Alexander E. Dudelzak, Guerman A. Pasmanik, Alexander Shilov and Evgueni Shklovskiy, for "A Device and Method for Non-Contact Sensing of Low-Concentration and Trace Substances".

Agent certificateur/Certifying Officer

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ABSTRACT

A device and method for non-contact (remote, standoff or in-situ) detection of chemical substances at low-concentrations or traces such as vapours of solid-phase or liquid materials, natural and anthropogenic atmospheric constituents, minor gaseous infrastructural leaks and industrial by-products, such as hazardous agents, hydro- and fluorocarbons, and others, the method is using a combination of two fundamental processes: a) inducing changes in the vapour refractive index, in particular, thermooptic effect in weakly absorbing substances, using spectrally selective light sharply resonant with absorption spectral line(s) of the sensed substance; and b) detecting the induced changes with laser beams (pulsed or CW) using coherent coupling of laser beams with orthogonal polarizations.

A DEVICE AND METHOD FOR NON-CONTACT SENSING OF LOW-CONCENTRATION AND TRACE SUBSTANCES

FIELD OF THE INVENTION

The present invention relates to remote sensing of low-concentration and trace substances in the form of gas, vapor or cloud of dust particles.

BACKGROUND OF THE INVENTION

When a laser pulse travels through a weakly absorbing substance a change in the index of refraction of the substance due to its heating is manifested along the path of the pulse. The thermal lens method, which utilizes a negative lens occurring as a result of radial profiling of refraction index of weakly absorbing materials, has been suggested for measuring absorption and used for spectrophotometry and spectroscopy. Other photothermally based spectroscopies include photoacoustic spectroscopy and photothermal deflection spectroscopy.

In the first publication, in which the thermal lens effect was described, " Long – Transient Effects in Lasers with Inserted Liquid Samples", by J.P. Gordon, R.C.C. Leiter, R.S. Moore, S.P.S. Porto, and J.R. Whinnery, Journal of Applied Physics 36, 3 (1965) buildup and decay transients of laser oscillation were observed when cells with some liquids were placed inside the resonator of a He-Ne laser operating at 633 nm. Similar but less pronounced effects were also observed with two solids. Transverse motion of the cell by about one beam width caused new transients similar to initial ones. It was believed that that the effects were caused by absorption of He-Ne laser emission in tested materials, producing a local heating in the vicinity of the beam and a lens effect due to transverse gradient of refractive index. Authors of that publication had found that absorption of $10^{-3} - 10^{-4}$ cm^{-1} is sufficient to produce the effect. After that publication it became obvious that the thermal lens effect provides a way of measuring weak absorption of light in transparent materials.

In "Accuracy and Sensitivity of the Thermal Lens Method for Measuring Absorption", by Domenico Solimini , Applied Optics, Vol. 5, No. 12, 1931 (1966) accuracy and sensitivity of the thermal lens method for measuring absorption was studied for the geometry when two lenses were inserted in an optical resonator. On the base of conducted studies the authors concluded that absorbencies of transparent materials cannot be measured in a simple way by photometric methods. They affirmed that the thermal lens effect provides a method for measuring absorbencies as low as 10^{-5} cm^{-1}. They found that the sensitivity of the method is related to the configuration of the resonator, nearly confocal resonators being the most sensitive. They pointed out, however that because near confocal resonators manifest effects harmful to precise measurements, cavities which are far from the confocal configuration appear to be the most suitable in practice.

In "Photothermal deflection spectroscopy and detection" by W.B.Jackson, N.M.Armer, A.C, Boccara, and D.Fournier, Applied Optics, Vol. 20, No.8, 1333 (1981) the theoretical foundation of photothermal deflection spectroscopy (PDF) has been developed. Two main configuration of PDF were considered: a) collinear photothermal deflection where the gradient of the index of refraction is both created and probed within the sample, and b) transverse photothermal deflection where the probing of the gradient of the index of refraction is accomplished in the thin layer adjacent to the sample. The latter approach is most suited for opaque samples and for materials with poor optical quality. The comparison with experiments conducted earlier by other authors and experimental verification of the theoretical prediction were conducted. In the summary of some photothermally based spectroscopies, the authors give sensitivity of different experimental set ups. The sensitivity in units of $(\alpha l)_{min}$ x pump power (Watts) ranges from 10^{-4} for micorophone photoacoustic spectroscopy to 10^{-8} for collinear PDF, and inform of special features pertinent to particular set ups.

In US 4,544,274 Cremers et al. disclose ~~a variant~~ of the thermal lens method, in which a cell containing the sample is inserted into a laser resonator for measurement of weak optical absorptions. In their method the output coupler of the resonator is deliberately tilted relatively

to CW laser beam circulating in the resonator, that gives rise to pulsations of the laser output, whose pulse width can be related to the sample absorptivity by a simple algorithm or calibration curve. Cremers et al. have demonstrated the measured absorption of 10^{-5} cm^{-1}.

In "Thermal Lens Spectrophotometry Using a Tunable Infrared Laser Generated by a Stimulated Raman Effect" by Shuichi Kawaasaki, Totaro Imasaka, and Nobuhiko Ishibashi, Anal. Chem., 59, 523 (1987) the thermal lens spectrophotometry, utilizing a tunable infrared laser source was applied to recording spectrum of ammonia in gaseous phase with spectral resolution of 0.1 cm^{-1}. The detection limit was 6% for the line at 1025.69 nm when available 0.13 – mJ, 10 – ns pulses at 1015 nm – 1040 nm were focused into a flow cell. Once more powerful infrared lasers are created the sensitivity of the method can be improved by several orders of a magnitude.

In US 4,310,762 Harris et al. a technique based on laser induced thermolens is disclosed. In that technique two cells are used, through which a laser beam travels. One of these being a reference cell, the other one being a sample cell. The cells are located at points in the beam path such that any modification in the beam caused by a change in the index of refraction of the medium in the reference cell is cancelled by the same medium in the sample cell. Any detectable modification in the beam, such as the beam expansion, change of its divergence, etc. as it escapes the sample cell is caused by the change in thermal lens in the material under identification.

In "Research of low–absorptive media for SBS in near infrared spectral band", by Bubis E.L., Var'gin V.V., Konchalina L.R., and Shilov A.A., *Optica e Spektroskopiya*, Vol.65, No.6, 1281 (1988) a combination of the thermal lens method and the dark–field method was used for determining weak absorption of liquids used in phase conjugate mirrors. This approach has demonstrated a possibility to use the thermooptical effect for remote detection of low concentration admixture in different transparent media. The authors focused 0.1 – 5 J, 0.2 - ms pulses of neodymium laser into a cell with liquid, the beam waist being 0.2 mm. A collimated probing beam of a He-Ne laser traversed through the waist along the axis of the

pumping beam and was blocked by a copper foil having 1 mm in diameter. A portion of the probing beam was scattered due to phase distortions caused by heat deposition in the focal region. The scattered component of the probing beam was registered by a photodetector. It was shown that so-called critical energy, which is a feature of tested liquid, particularly its absorbance, determines the weakest distortions detectable. In fact, it was possible to detect heat–induced distortion at 1/100 of the critical energy. With this method the authors measured absorbance as low as 10^{-6} cm^{-1}.

N.F. Andreyev, E.A. Khazanov, S.V. Kuznetsov, G.A.Pasmanik, E.I.Shkolvsky, and V.S.Sidorin, IEEE J. of Quant. Electr., Vol.27, No. 9, 1024 (1991). in "Locked Phase Conjugation for Two Beam Coupling of Pulse Repetition Rate Solid–State Lasers", teaches a method of coherent beam coupling.

Methods and devices of the prior art in which the thermooptical effect was exploited for determining weak light absorption in different transparent media, finding trace substances and for spectroscopic needs, disclose high–sensitive methods and devices for laboratory environment only. Also, there have been developed numerous optical techniques, based mainly on lidars, capable of remote detecting trace substances in air, on water and ground surface. Previous art disclosed no evidence of using thermooptical effect in remote sensing of trace gases, vapors and dust particles.

All documents discussed above disclose no evidence of using thermooptical effect in remote sensing of trace substances. At the same time, if developed such a method would provide effective tool for remote detection with high spatial resolution of ultra-low concentration substances, including vapor / gaseous leaks and side products of hazardous industry and trace explosive materials.

Knowing that the thermolens effect can be used for remotely sensing of low concentration substances in air, whichever these substances are: gaseous, vaporous, or representing a cloud of dust particles; and that what is essential for security purposes is that the effect of

thermolensing can be applied to remote sensing of trace substances with high spatial resolution, we have now extended the thermooptically–based method of detecting low concentration substances beyond a laboratory environment by developing a device and method capable remote detection with high spatial resolution of ultra-low concentration substances, including vapor / gaseous leaks and side products of hazardous industry and trace explosive materials.

SUMMARY OF THE INVENTION

It is an object of the present invention to develop a system to detect low concentration and trace substances outside the laboratorial environment.

It is an object for the present invention is to detect trace substances in air.

It is another object of the invention is to detect trace substances in a thin layer near targets.

It is yet another object is to locate with high spatial resolution trace substances in a thin layer near targets.

Yet one more object is to determine with high spatial resolution trace substance in air near targets.

One other object of this invention is to provide a device using the method disclosed in the invention.

The present invention seeks to provide a device for non-contact detection of low concentration and trace substances, including:

a first laser beam source;

a second laser beam source;

a first polarizing means;

a second polarizing means;

a third polarizing means;

a fourth polarizing means;

an objective lens;

a first photo-detection means, and

a second photo-detection means,

wherein, a first laser beam emitted by the first laser beam source is split into a first and a second split laser beams by the first polarizing means, the first and second split laser beams delivered to the second polarizing means , the second polarizing means merging the first and the second split reference laser beams and delivering to the objective lens, the objective lens focusing the first and the second split laser beams which are delivered to a target , the target backscattering the first and the second split laser beams, the third polarizing means combining the first and the second backscattered split laser beams forming an output laser beam 6, the fourth polarizing means splitting the output 6 into a third split laser beam 8 directed to the first photo-detection means and a second split laser beam 9, directed to the second photo-detection means, and

wherein the first and the second split laser beams are delivered to the target within a predetermined interval when the laser beam is a pulse laser beam, and

wherein a pumping laser beam emitted by the pumping laser beam source is delivered to the target region overlapping all beams, and

wherein, a second laser beam emitted by the first laser beam source is split into a first and a second split probing laser beams by the first polarizing means, the first and second probing laser beams delivered to the second polarizing means, the second polarizing means merging the first and the second split probing laser beams and delivering to the objective lens, the objective lens focusing the first and the second split probing laser beams which are delivered to the target within a predetermined interval, the target backscattering the first and the second split probing laser beams, the third polarizing means combining the first and second backscattered split probing laser beams forming an output probing laser beam 7, the fourth polarizing means then splitting the output probing laser beam7 into a second probing

laser beam 10 directed to the first photo-detection means and a third probing laser beam11, directed to the second photo-detection means when the laser beam is a pulse laser beam, and

wherein, the pumping laser beam is emitted by the pumping laser beam source within a predetermined interval is focused by the objective lens and delivered to the target region after the delivery of the first and the second reference laser beams, after the first probing laser beam and before the delivery of the second probing laser beam, overlapping all beams when the laser beam is a pulse laser beam, and

wherein, the first and second photo-detection means receiving the laser beams and detecting and identifying the presence of the substance of interest.

The present invention also seeks to provide a method for non-contact detection of low concentration and trace substances including the steps of:

splitting a first polarized laser beam A generated by a first laser beam source with a first polarizing means into a first and a second split laser beams;

merging the first and second split laser beams with a second polarizing means and directing the first and second split laser beams to a focusing objective lens;

sending a pumping laser beam 3 generated by a second laser beam source 2 to the objective lens, the wavelength matching the absorption line of a target substance;

splitting a second laser beam B generated by the first laser beam source with the first polarizing means into a first and a second split probing laser beams when the laser beam is a pulse laser beam;

merging the first and a second split probing laser beams with the second polarizing means and directing the first and a second split probing laser beams to a focusing objective lens and to the target when the laser beam is a pulse laser beam;

delivering the first and second split laser beams and the pumping polarized laser beam 3 to the target at the same time when the laser beam is a continuous wave laser beam.

delivering , within a predetermined interval, the first and second split laser beams to the to the target before the delivery of the first and a second split probing laser beams, when the laser beam is a pulse laser beam;

delivering, within the predetermined interval, the pumping polarized laser beam 3 to the target after the delivery of the first split probing laser beam and before the delivery of the second split probing laser beams, when the laser beam is a pulse laser beam;

the objective lens focusing the merged laser beams and the pumping laser beam so that the beam waists at the focus of the objective lens in the target volume overlap each other;

the target backscattering the merged laser beams;

a third polarizing means combining the merged laser beams producing a third laser beam 6 the third polarizing means producing an additional fourth laser beam 7, when the laser beam is a pulse laser beam;

a fourth polarizing means splitting the third laser beam 6 into a third split laser beam 8 and a fourth split laser beam 9, the fourth polarizing means additionally splitting the additional fourth laser beam 7 into a fifth split laser beam 10 and a sixth split laser beam 11 when the laser beam is a pulse laser beam, and

sending the split laser beams to the first and the second photo-detection means identifying the presence of the target substance

BRIEF DESCRIPTION OF DRAWINGS

FIGURE 1 is a diagram of the time format for sequences of pulses which can be used in a possible system relied on the method disclosed in the present invention;

FIGURE 2 is a schematic of a possible optical system, employing the effect of laser induced change in the refractive index, in particular thermooptical effect for remote detection with high spatial resolution of trace substances in air near a target, and

FIGURE 3 is an a schematic representation of focusing of light beams into target region.

DETAILED DESCRIPTION OF THE INVENTION

The present invention seeks to provide remote sensing of trace substances in the form of gas, vapor or cloud of dust particles, which resonantly absorb optical radiation in UV, visible or infra-red regions, using the effect of laser–induced change of refractive index, in particular thermooptic effect. The nonlinear phase shift appears between two probing coherent pulses, which have been sent subsequently to and scattered subsequently from the target region, if the refractive index was changed in the target region under the action of pumping pulses over time interval between these pulses. An optical system separates s – and p – components of coherently coupled reference and probing pulses, back scattered from target region, and sends them to photodiodes; the change in the phase shift is registered by electronics, and the conclusion is made about presence of the substance under search in target region.

In the present invention the heating pulse is focused at the targeted area to provide noticeable absorption over a short distance corresponding to the focal waist, and a sensing probing pulse modified by the change in the refractive index in the focal area, due to presence of low concentration substance resonantly absorbing the heating pulse, check via coherent beam combining with a reference probing pulse transmitted through non-perturbed focal region. The method disclosed in the present invention takes advantage of a long-focal-distance objective (typical focal distance in tens of meters range) and high spatial resolution due to a narrow beam waist (typical beam waist in hundreds of microns range). The method disclosed in the present invention provides remote detection of trace substances near a condensed target, including ground surface, and what is more important, the location of substances can be determined with unprecedented spatial resolution.

To achieve the foregoing objectives, and in accordance with the purposes of the present invention, methods disclosed may comprise but not be limited by: 1. a pumping laser beam in a form of a continuous sequence of nanosecond pulses directed to a target region; 2. a probing laser beam in a form of a continuous sequence of nanosecond pulses, split by two beams, each in a form of a continuous sequence of nanosecond pulses, one of these beams being a

reference beam, the other one being a probing beam directed to a target region; 3. an objective to focus reference, pumping and probing beams within a narrow layer of air near a target; 4. a set of optical components, including but not limited by: mirrors, beam splitters, polarizers, half – wave plates, and Faraday rotators; 5. an electronic equipment, including but not limited by photodiode, photo-multiplier, and a microprocessor

Besides, in order to increase sensitivity of detection the present invention utilizes the method of coherent combining of light beams with orthogonal polarizations

In one variant of the present invention, sequences of pulses are time – shifted with respect to each other so, that a burst of five pulses provides a single detecting event. These pulses are reference, pumping, and probing pulse, respectively. Within each burst, the pulses are sent to the target region according to the following time format. First reference pulses 1 and 2 are focused by the objective into the region. Next, probing pulse 4 followed by pumping pulse 3 is focused into target region, and finally probing pulse 5 is focused. According to the invention the detection of a trace substance uses the laser induced change in the refractive index, in particular thermooptical effect, includes the coherent beam combining of received optical pulses, and occurs as follows: The objective collects back scattered reference and probing pulses, which were focused by the same objective into unperturbed target region. A set of optical components, providing delivery of reference and probing pulses to target region, sends back scattered reference and probing pulse to the input /output polarizer (to which the linear polarized probing pulses were sent prior its splitting into two sequences). If the pumping pulse didn't change the refractive index in target region, and hence didn't perturb the region, there would be equal ratios between s – and p – components for reference and probing pulses. However, if there was a change in the refractive index over period between probing pulse 4 and probing pulse 5, the scattered probing pulses 5 gets additional phase shift while traversing the perturbed region. In this case there wouldn't be equal ratios between s – and p – components for reference and probing pulses, which indicate on the presence of the substance under search in target region.

In another variant of the present invention, a continuous wave (CW) laser is used for generating a CW beam, which is further split by into CW s – polarized and p – polarized beams, and further are merged into one beam directed to the objective and further to target region. The detecting event corresponds to a small time interval around the moment of generating the pumping pulse. The same objective collects back scattered CW beam, and a set of optical components, providing delivery of CW beam (and its s- and p – components) to target region, sends back scattered CW beam (its s- and p-components) to the input /output polarizer (to which the linear polarized CW beam was sent prior its splitting into s – and p - components). If the pumping pulse didn't change the refractive index in target region, and hence didn't perturb the region, there would be no change in the waveform (constant) of both s – and p – components of the recieved CW signal after the moment of generating the pumping pulse. However, if there was a change in the refractive caused by the pumping pulse transients would appear in both s – and p – waveform following (with a small delay) pumping pulse, which indicate on the presence of the substance under search in target region.

If a focal region contains a medium, which resonantly absorbs an incident laser pulse, a change in the refractive index of the above medium is manifested as a result of heat deposited into the focal region during the pulse - to medium interaction. This change in the refractive index causes the change in the phase of the wave scattered by a target and transmitted backward through the heated focal region towards the objective, with regard to the phase of the wave scattered by the same target and transmitted backward through unheated focal region towards the same objective. We note that resonant absorption can induce change in the refractive index via different nonlinear optical mechanisms, and thermal – optical effect here is considered for distinctness only.

The additional phase shift is determined by the following formula: $\Delta\phi = \frac{2\cdot\pi}{\lambda}\cdot l\cdot\Delta n$, where λ is the wavelength of the emission focused into the target region, l is the length of the beam waist, Δn is the change in the refractive index due to heating of the medium in the focal waist.

Fig.1. Schematic representation of possible CW sequences of pulses' focused into a target region (interpulse and interburst periods are shown as examples, pulse's numbering corresponds to the description of present invention)

In order to explain how the proposed method works, it is necessary to address the time format of pulses depicted in Fig.1, and the optical schematic of a possible system for remote sensing of gas admixtures, shown in Fig.2. According to the time format there are five pulses following one after another in each sending (burst). Pulses 1 and 2 are reference pulses, pulse 3 is the pumping (heating) pulse, and pulses 4 and 5 are probing pulses, respectively. In each sending the reference and probing pulses stem from two pulses, which are referred to as input probing pulse 01 and 02 (not shown in the time format).

Fig.2. is a simplified schematic of a possible optical system for remote detection of low concentration gas admixture in air. The components shown in Fig.2, except for mirror M5, serve for delivery of input probing pulses 01 and 02, splitting them into reference and probing pulses, and sending the latter to target region and back (scattered pulses) from target region to photodiodes for further processing. Dichroic mirror M5 reflects pumping pulse 3 towards the telescope, objective, and further to target region. In the embodiment, p - polarized input probing pulses 01 and 02 (following each other) travel through polarizer P1, Faraday rotator FR1, half wave plate HWP1, and having reflected by polarizer P2 and mirror M1, are sent, as s – polarized, to half wave plate HWP 2. HWP 2 is oriented such that at the exit of HWP 2 the linear polarization of both probing pulses 01 and 02 has orientation 45^0. Pulse 01 with this polarization further hits polarizer P3, which splits the above probing pulse into p - and s - polarized reference pulses 1 and 2. Pulse 1 with p – polarized travels further through polarizer P4, small aperture A (for selecting lowest spatial mode), Faraday rotator FR2, dichroic mirror M5, the telescope, and further is focused into the focal region by the objective. Reference pulse 2 is reflected by polarizer P3, mirrors M2, M3, and further by polarizer P4 to aperture A, and further travels along the same path as reference pulse 1. Having back scattered by the target, the reference pulses (in fact, a small portion of these pulse) are captured by the

objective, and sent back to the telescope, dichroic mirror M5, and further to Faraday rotator FR2.

Back scattered reference pulse 1 at the exit of FR2 has s – polarization (due to double passing through the Faraday rotator). Reference pulse 1 is further selected by aperture A, and reflected by polarizer P4, and further is directed after reflections from mirrors M3 and M2 to polarizer P3. Note that at polarizer P3, now s – polarized reference pulse 1 has phase $\Phi 1$.

In the same way, reference pulse 2 with now p – polarization at the exit of FR2 is further selected by aperture A, transmits through polarizer P4 and is sent to polarizer P3, at which now p – polarized reference pulse 2 has phase $\Phi 2$. At the left -hand facet of polarizer P3 both reference pulses are coherently coupled, resulting in output reference pulse 6. If there wasn't the change in the refractive index over the interval, Δt_{1-2}, between pulses 1 and 2 (which is true if Δt_{1-2} is sufficiently small), then phase shift $\Phi 2 - \Phi 1 = 0$, and the polarization of the combined reference pulse 6 would be the same as that of the input linear polarized pulse P01. For the time format, shown as the example, $\Delta t_{1-2} = 20$ ns.

In 20 ns after pulse 01, second probing pulse 02 hits polarizer P3, which splits the pulse 02 into p - and s - polarized probing pulses 4 and 5, respectively. Pulse 4 with p – polarization travels further through polarizer P4, small aperture A (for selecting lowest spatial mode), Faraday rotator FR2, dichroic mirror M5, the telescope, and further is focused into the focal region by the objective. Probing pulse 5 with s - polarization is reflected by polarizer P3, mirrors M2, M3, polarizer P4 and further is directed through small aperture A along the same path as probing pulse 4. Like in the case of reference pulses 1, 2 there is a delay between probing pulses 4 and 5. In our example this delay is 20 ns. Having back scattered by the target, probing pulses 4 and 5 (in fact, a small portion of these pulses) are captured by the objective, and sent back to the telescope, dichroic mirror M5, and further to Faraday rotator FR2.

Back scattered probing pulse 4 at the exit of FR2 has s – polarization (due to double passing through the Faraday rotator). Probing pulse 4 is further selected by aperture A, and reflected by polarizer P4, and further is directed after reflections from mirrors M3 and M2 to polarizer P3. Note that at polarizer P3, now s – polarized reference pulse 4 has phase $\Phi 4$, which is the same as $\Phi 1 = \Phi 2$, because of small time interval between probing pulse 4 and references pulses 1, 2. In the same way, probing pulse 5 with now p – polarization at the exit of FR2 is further selected by the aperture, transmits through polarizer P4 and is sent to polarizer P3, at which now p – polarized probing pulse 5 has phase $\Phi 5$. At the left - hand facet of polarizer P3 both probing pulses are coherently coupled resulting in output probing pulse 7.

Note, that after probing pulse 4 but before probing pulse 5, pumping pulse 3 is focused into target region. Powerful laser pulse 3 at the wavelength tuned to the absorption line of the target media is reflected by mirror M5, passes through the telescope, and further is focused into the target region by the objective. If there wasn't a change in the refractive index over the interval, Δt_{4-5}, between probing pulses 4 and 5 (which is true if, pumping pulse 3 didn't induce the change in the refractive index), then phase shift $\Phi 5 = \Phi 4$, and the polarization of combined probing pulse 7 would be the same as that of the input linear polarized pulse 02. In the chosen time format pumping pulse 3 reaches the focal region 20 ns after probing pulse 4, but 20 – ns before probing pulse 5. However, if there is gas admixture resonantly absorbing the pumping pulse, the phase for the backscattered probing pulse 5 traveling through the focal waist would be different from that of the probing pulse 4. We underline that optical paths for probing pulses 4 and 5 differ in latter case by $l \cdot \Delta n$, therefore the phase shift between these two pulses at the exit of polarizer 3 (at its left – hand facet), $\Delta\Phi = \Phi 5 - \Phi 4 = \frac{2 \cdot \pi}{\lambda} \Delta n \cdot l$.

If $\Delta\Phi = 0$, (no pump – affected change in the refractive index) the pulses 4 and 5, coherently combined by polarizer P3, would result in s - polarized output probing pulse 7 at the exit of HWP2 (at its left –hand side). This pulse is reflected by mirror M1, further reflected by polarizer P2 to HWP1 and, having passed through FR1, is further reflected by polarizer P1 to photodiode PD1.

If $\Delta\Phi \neq 0$, a p - component appears in the polarization of pulse 7. Depending upon the absolute value of $\Delta\Phi$, a certain portion of the output probing pulse is transmitted through by P2 to photodiode PD 2. Thus, if the pumping pulse causes some change in the refractive index in the focal region as a result of resonantly absorbing admixture, probing pulse 7, stemming from back scattered pulse 5, produces a signal P_{Prob} at photodiode PD2.

In practice, one can expect some depolarization of reference and probing pulses while they are passing through optical components. This depolarization is equal for pulses traversing the same optical components, therefore the appearance of p – components at the HWP 2 exit is unavoidable even in backscattered references pulses combined at polarizer 3. From comparison of ratios $\frac{S_{ref}}{P_{ref}}$ and $\frac{S_{prob}}{P_{prob}}$ a conclusion can be made about the presence of the substance under search in target region. (S_{ref}, P_{ref}, S_{prob}, P_{prob}, are the signal, corresponding to received S - and P – components of reference pulse 6 and probing pulse 7, respectively.

In a similar manner the operation of a possible system, utilizing the method disclosed in the present invention, but relied on CW probing rather than pulsed one can be described.

In the preferred embodiment of the device of the present invention it is provided a device including a first laser beam source; a second laser beam source; a first polarizer; a second polarizer; a third polarizer; a fourth polarizer; an objective lens; a first and a second photo-detector. In the device, a first laser beam emitted by the first laser beam source is split into a first and a second split reference laser beams by the first polarizer, the first and second laser beams delivered to the second polarizer, the second polarizer merging the first and the second split reference laser beams and delivering the laser beams to the objective lens, the objective lens focusing the first and the second laser beams which are delivered to a target, the target backscattering the first and the second laser beams, the third polarizer combining the first and the second backscattered laser beams forming an output reference laser beam 6, the fourth polarizer splitting the output reference laser beam 6 into a third reference laser beam 8 directed to the first photo-detector and a second reference laser beam 9, directed to the second

photo-detector. The first and the second split reference laser beams are delivered to the target within a predetermined interval when the laser beam is a pulse laser beam.

A pumping laser beam is then emitted by the pumping laser beam source and delivered to the target region overlapping all beams.

When using pulse laser beam, a second laser beam (probing laser beam) also emitted by the first laser beam source is split into a first and a second split probing laser beams also by the first polarizer, the first and second laser beams delivered to the second polarizer, the second polarizer merging the first and the second split probing laser beams and delivering to the objective lens, the objective lens focusing the first and the second laser beams which are delivered to the target within a predetermined interval, the target backscattering the first and the second laser beams, the third polarizer combining the first and second backscattered laser beams forming an output probing laser beam 7, the fourth polarizer then splitting the output probing laser beam7 into a second probing laser beam 10 directed to the first photo-detector and a third probing laser beam11, directed to the second photo-detector. Also, the pumping laser beam is emitted by the pumping laser beam source within a predetermined interval and focused by the objective lens and delivered to the target after the delivery of the first and the second reference laser beams, after the first probing laser beam and before the delivery of the second probing laser beam, overlapping all beams.

The first and second photo-detector receiving the laser beams will detect and identify the presence of the substance of interest.
In this preferred embodiment the device includes a first faraday rotator, a first half-wave plate, a second half-wave plate, and a first and a second mirror. The device further including an aperture, a second and a third faraday rotator, a dichroic mirror and a telescope. The first and second photo-detectors are photodiodes.

When the laser beam is a pulse laser beam, the photodiodes will measure electrical signals $S_{reference}$, $P_{reference}$, $S_{probing}$, $P_{probing}$, corresponding to the detection of the third reference laser

beam 8 the second reference laser beam 9, the second probing laser beam 10 and the third probing laser beam11,

identifying the presence of the target substance in a target volume by comparing the $\frac{S_{ref}}{P_{ref}}$ and $\frac{S_{prob}}{P_{prob}}$ ratios .

The invention can be effectively used for search for oil / gas pipe leakage; detection of explosive and nuclear materials, survey and remote evaluation of agricultures' fields, detection of polluted sea areas, search for minerals, etc.

In another preferred embodiment of the device a device for non-contact detection of low concentration and trace substances, including:

a laser beam source 1;

a laser beam source 2;

a first polarizer 1;

a second polarizer 2;

an objective lens;

a first photodiode 1, and

a second photodiode 2,

wherein, a first polarized laser pulsed beam emitted by the laser beam source 1 is split into a beam 1 and a beam 2 with s – and p – polarization, respectively by the first polarizer 1, beam 1 and beam 2 delivered to the second polarizer 2, second polarizer 2 merging beam 1 and beam 2 from the point of merging to the focusing objective lens, a pumping laser beam 3 emitted by the laser beam source 2 with the wavelength matching the resonance line of the target substance, is delivered to the focusing objective lens, , and

wherein a reference pulse 1 with p – polarization and a reference pulse 2 with s – polarization are delivered to objective lens before the delivery of the pumping pulse 3 to the objective lens within probing events; pumping pulse 3 of the laser source 2 is delivered to the objective lens after the delivery of the reference pulse 1 and the reference pulse 2 within probing events, and

wherein a probing pulse 4 with p – polarization is delivered to the objective lens before the delivery of pumping pulse 3, and a probing pulse 5 with s – polarization is delivered to the objective lens after the delivery of pumping pulse 3; and

wherein the objective lens pinpoints and focuses the beams, corresponding to the references pulses, the pumping pulses and the probing pulses, such that their waists in the focus of the objective lens in the target region overlap each other, and

wherein the target sends backscattered reference pulses 1 and 2 and the backscattered probing pulses 4 and 5 to the first polarizer 1 where a s – polarized reference pulse 1 is combined with a p – polarized reference pulse 2, originating a reference pulse 6 and a s – polarized probing pulse 4 is combined with a p – polarized probing pulse 5 within probing events originating a probing pulse 7, and

wherein the reference pulse 6 is split into a s – polarized reference pulse 8 and a p – polarized reference pulse 9, and the probing pulse 7 is split into s – polarized probing pulse 10 and p – polarized probing pulse 11, and

wherein the s – polarized reference pulse 8 and the s – polarized probing pulse 10 are sent to the photodiode 1, and the p – polarized reference pulse 9 and the p – polarized probing pulse 11 are sent to the photodiode 2, and the photodiodes 1 and 2 identify the presence of the target substance.

In another preferred embodiment of the device a device for non-contact detection of low concentration and trace substances, including:

a laser beam source 1;

a laser beam source 2;

a first polarizer 1;

a second polarizer 2;

an objective lens;

a first photodiode 1, and

a second photodiode 2,

wherein, a first linear polarized beam of a CW laser 3 emitted by the laser beam source 1 is split by the first polarizer 1 into a CW - beam 1 and a CW - beam 2 with s – and p

– polarization, respectively; beam 1 and beam 2 delivered to the second polarizer 2, the second polarizer 2 merging beam 1 and beam 2 from the point of merging to the focusing objective lens; a pumping laser beam 3 emitted by the laser beam source 2 with the wavelength matching the resonance line of the target substance, is delivered to the focusing objective lens, and

the CW – beam 1 and the said CW – beam 2 are delivered to the objective lens, the objective lens focusing the CW beam 1, the CW beam 2 and the pumping beam 3 such that their waists in the focus of the objective lens in the target overlap each other, and

wherein the target sends a backscattered CW beam 1 and a backscattered CW beam 2 to the polarizer 1 such that a s – polarized CW beam 1 is combined with a p – polarized CW beam 2, originating a CW beam 4, and

wherein CW beam 4 is split into a s – polarized CW beam 5 and a p – polarized CW beam 6, and

wherein the s – polarized CW beam 5 is sent to photodiode 1, and the p – polarized CW beam 6 is sent to photodiode 2; the photodiodes measuring the waveforms S and P of electrical pulses at outputs of photodiode 1 and photodiode 2, respectively; and identify the presence of the target substance.

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Claims

1. A device for non-contact detection of low concentration and trace substances, including:

a first laser beam source;

a second laser beam source;

a first polarizing means;

a second polarizing means;

a third polarizing means;

a fourth polarizing means;

an objective lens;

a first photo-detection means, and

a second photo-detection means,

wherein, a first laser beam emitted by the first laser beam source is split into a first and a second split laser beams by the first polarizing means, the first and second split laser beams delivered to the second polarizing means , the second polarizing means merging the first and the second split reference laser beams and delivering to the objective lens, the objective lens focusing the first and the second split laser beams which are delivered to a target , the target backscattering the first and the second split laser beams, the third polarizing means combining the first and the second backscattered split laser beams forming an output laser beam 6, the fourth polarizing means splitting the output 6 into a third split laser beam 8 directed to the first photo-detection means and a second split laser beam 9, directed to the second photo-detection means, and

wherein the first and the second split laser beams are delivered to the target within a predetermined interval when the laser beam is a pulse laser beam, and

wherein a pumping laser beam emitted by the pumping laser beam source is delivered to the target region overlapping all beams, and

wherein, a second laser beam emitted by the first laser beam source is split into a first and a second split probing laser beams by the first polarizing means, the first and second probing laser beams delivered to the second polarizing means, the second polarizing means merging the first and the second split probing laser beams and delivering to the objective

lens, the objective lens focusing the first and the second split probing laser beams which are delivered to the target within a predetermined interval, the target backscattering the first and the second split probing laser beams, the third polarizing means combining the first and second backscattered split probing laser beams forming an output probing laser beam 7, the fourth polarizing means then splitting the output probing laser beam7 into a second probing laser beam 10 directed to the first photo-detection means and a third probing laser beam11, directed to the second photo-detection means when the laser beam is a pulse laser beam, and

wherein, the pumping laser beam is emitted by the pumping laser beam source within a predetermined interval is focused by the objective lens and delivered to the target region after the delivery of the first and the second reference laser beams, after the first probing laser beam and before the delivery of the second probing laser beam, overlapping all beams when the laser beam is a pulse laser beam, and

wherein, the first and second photo-detection means receiving the laser beams and detecting and identifying the presence of the substance of interest.

2. The device of Claim 1, wherein the first polarizing means is a first polarizer.

3. The device of Claim 1, wherein the second polarizing means is a second polarizer.

4. The device of Claim 1, wherein the third polarizing means is a third polarizer.

5. The device of Claim 1, wherein the fourth polarizing means is a fourth polarizer.

6. The device of Claim 1, further including a first faraday rotator, a first half-wave plate, a second half-wave plate, a first and a second mirror, an aperture, a second and a third faraday rotator, a dichroic mirror and a telescope.

7. The device of Claim 1, wherein the first photo-detection means is a first photodiode.

8. The device of Claim 1, wherein the second photo-detection means is a second photodiode.

9. A method for non-contact detection of low concentration and trace substances including the steps of:

splitting a first polarized laser beam A generated by a first laser beam source with a first polarizing means into a first and a second split laser beams;

merging the first and second split laser beams with a second polarizing means and directing the first and second split laser beams to a focusing objective lens;

sending a pumping laser beam 3 generated by a second laser beam source 2 to the objective lens, the wavelength matching the absorption line of a target substance;

splitting a second laser beam B generated by the first laser beam source with the first polarizing means into a first and á second split probing laser beams when the laser beam is a pulse laser beam;

merging the first and a second split probing laser beams with the second polarizing means and directing the first and a second split probing laser beams to a focusing objective lens and to the target when the laser beam is a pulse laser beam;

delivering the first and second split laser beams and the pumping polarized laser beam 3 to the target at the same time when the laser beam is a continuous wave laser beam.

delivering , within a predetermined interval, the first and second split laser beams to the to the target before the delivery of the first and a second split probing laser beams, when the laser beam is a pulse laser beam;

delivering, within the predetermined interval, the pumping polarized laser beam 3 to the target after the delivery of the first split probing laser beam and before the delivery of the second split probing laser beams, when the laser beam is a pulse laser beam;

the objective lens focusing the merged laser beams and the pumping laser beam so that the beam waists at the focus of the objective lens in the target volume overlap each other;

the target backscattering the merged laser beams;

a third polarizing means combining the merged laser beams producing a third laser beam 6 the third polarizing means producing an additional fourth laser beam 7, when the laser beam is a pulse laser beam;

a fourth polarizing means splitting the third laser beam 6 into a third split laser beam 8 and a fourth split laser beam 9, the fourth polarizing means additionally splitting the additional fourth laser beam 7 into a fifth split laser beam 10 and a sixth split laser beam 11 when the laser beam is a pulse laser beam, and

sending the split laser beams to the first and the second photo-detection means identifying the presence of the target substance

10. A method for remote detection at medium distances of low concentration substances resonantly absorbing laser beam pulses, using the effect of laser beam induced change in the refractive index in target region, which comprises the following steps:

splitting a linear polarized beam of a repetitively pulsed Q – switch laser 1 by polarizer 1 into beam 1 and beam 2 with s – and p – polarization, respectively;

merging said beam 1 and said beam 2 on the path from the place of merging to a focusing objective;

sending of pumping beam of a repetitively pulsed Q – switch laser 2, capable of generating pumping pulses 3 with the wavelength matching the resonance line of target substance, to said objective;

delivery (within each probing event) of reference pulse 1 with p – polarization and reference pulse 2 with s – polarization to said objective before the delivery of said pumping pulse 3 to said objective;

delivery (within each probing event) of said pulse 3 of said laser 2 to said objective after the delivery of said reference pulse 1 and said reference pulse 2 to said objective;

delivery (within each probing event) of probing pulse 4 with p – polarization before said pumping pulse 3, and probing pulse 5 with s – polarization after said pumping pulse 3 to said objective;

pinpointing and focusing of beams, corresponding to said references pulses, said pumping pulses and said probing pulses, by said objective such that their waists in the focus of said objective in said target region overlap each other;

Sending (within each probing event) backscattered reference pulses 1,2 and said backscattered probing pulses 4, 5 from said target region to said polarizer 1 such that now s – polarized said reference pulse 1 can be combined with now p – polarized said reference pulse 2, and now s – polarized said probing pulse 4 can be combined with now p – polarized said probing pulse 5.

combining said s – polarized reference pulses 1 with said p – polarized reference pulse 2 to obtain reference pulse 6, and said s – polarized probing pulse 4 with said p – polarized probing pulse 5 to obtain probing pulse 7;

splitting of said reference pulse 6 into s – polarized reference pulse 8 and p – polarized reference pulse 9, and said probing pulse 7 into s – polarized probing pulse 10 and p – polarized probing pulse 11;

sending said s – polarized reference pulse 8 and s – polarized probing pulse 10 to photodiode 1, and said p – polarized reference pulse 9 and p – polarized probing pulse 11 to photodiode 2.

measuring amplitudes of electrical signals S_{ref}, P_{ref}, S_{prob}, P_{ref}, corresponding to detection of s – polarized reference pulse 8, p – polarized reference pulse 9, s – polarized probing pulse 10, p – polarized probing pulse 11, respectively.

making a conclusion about presence of said target substance in said target region from comparison of $\frac{S_{ref}}{P_{ref}}$ and $\frac{S_{prob}}{P_{prob}}$ ratios.

11. A method according to claim 10, wherein said merging of said beam 1 and said beam 2 is provided by polarizer 2;

12. A method according to claims 10, 11, wherein said reference pulse 1 and said probing pulse 3 transmit through said polarizer 1 and said polarizer 2, and further are delivered to Faraday rotator 3;

13. A method according to claims 10,11, wherein said reference pulse 4 and said probing pulse 5 after said polarizer 1 are further reflected by two mirrors and said polarizer 2, and further delivered to said Faraday rotator 3;

14. A method according to claims 10, 11, 12, 13, wherein after said polarizer 2 said reference pulses 1,2 and said probing pulses 4,5 transmit through Faraday rotator 3, a tilted dichroic mirror, expanding telescope, and are further focused by said objective into said target region;

15. A method according to claim 10, wherein said beam 3 is sent coaxially with said pulses 1,2,4,5 to said objective through reflection of said beam 3 by said dichroic mirror;

16. A method according to claim 14, wherein said two mirrors form the optical delay to provide delivery of said reference pulse 1 to said target region before said reference pulse 2, and the delivery of said probing pulse 4 to said target region before delivery of said probing pulse 5;

17. A method according to claims 11, 12, wherein an aperture is used between said polarizer P2 and Faraday Rotator 3 to select lowest spatial mode of said backscattered reference pulses 1,2 and said probing pulses 4,5

18. A method according to claims 11, 12, wherein instead of laser 1 intended for generation of said linear polarized beam, a split - off portion of said beam 3, is converted by optical means into a beam with shifted wavelength, and is further delivered to polarizer P1;

19. A method according to claims 11, 13 wherein sending of said s – polarized reference pulse 8 and s – polarized probing pulse 10 to photodiode 1, and said p – polarized reference pulse 9 and p – polarized probing pulse 11 to photodiode 2 is provided by a polarizer

20. A method according to claim 11, wherein electrical pulses from said photodiodes 1 and 2 are analyzed by electronics, and electrical pulse corresponding to a detected substance is displayed.

21. A method for remote detection at medium distances of low concentration substances resonantly absorbing laser beam pulses, using the effect of laser induced change in the refractive index in target region, which comprises the following steps:

Splitting a linear polarized beam of a CW laser 3 by polarizer 1 into CW - beam 1 and CW - beam 2 with s – and p – polarization, respectively;

Merging said CW beam 1 and said CW beam 2 on the path from the place of merging to a focusing objective;

Sending of pumping beam 3 of a repetitively pulsed Q – switch laser 2 with the wavelength matching the resonance line of target substance, to said objective;

Delivery of said CW – beam 1 and said CW – beam 2 to said objective;

Focusing of said CW beam 1, said CW beam 2 and said beam 3 by said objective such that their waists in the focus of said objective in said target region overlap each other;

Sending backscattered said CW beam 1 and said CW beam 2 to said polarizer 1 such that now s – polarized said CW beam 1 can be combined with now p – polarized said CW beam 2;

Combining said s – polarized CW beam 1 with said p – polarized CW beam 2 to obtain CW beam 4;

Splitting CW beam 4 into s – polarized CW beam 5 and p – polarized CW beam 6;

Sending said s – polarized CW beam 5 to photodiode 1, and said p – polarized CW beam 6 to photodiode 2;

Measuring of waveforms S and P of electrical pulses at outputs of photodiode 1 and photodiode 2, respectively;

Making a conclusion about presence of said substance under search in said target region by comparing recorded said outputs.

22. A method for non-contact (remote, standoff or in situ) detection of low concentration substances resonantly absorbing light, using coherent laser sensing of the effect of light-induced changes in the refractive index in the target vapour volume, which comprises the following steps:

splitting with polarizer 1 a linearly polarized coherent beam (pulsed or CW) generated by laser beam source 1 into beam 1 and beam 2 with s- and p-polarization, respectively;

merging / coherently coupling said beam 1 and said beam 2 on the path from the point of merging to a focusing objective;

pointing the pumping beam 3 generated by the light source 2 at the wavelength(s) sharply matching absorption line(s) of the target substance, to said objective;

delivering (within each probing event) the reference beam 1 of p-polarization and the reference beam 2 of s-polarization to said objective before the delivery of said pumping beam 3 to said objective;

delivering (within each probing event) said beam 3 of said laser 2 to said objective after the delivery of said reference beam 1 and said reference beam 2 to said objective;

delivering (within each probing event) probing beam 4 of p-polarization before said pumping beam 3, and probing beam 5 of s-polarization after the delivery of the said pumping beam 3 to said objective;

with said objective, pointing and focusing said reference, pumping and probing beams so that the beam waists at the focus of said objective in the target volume overlap each other;

pointing (within each probing event) backscattered reference beams 1,2 and said backscattered probing beams 4, 5 from the target area to said polarizer 1 such that now s-polarized said reference beam 1 can be combined with now p-polarized said reference beam 2, and now s- polarized said probing beam 4 can be combined with now p- polarized said probing beam 5.

combining said s-polarized reference beam 1 with said p-polarized reference beam 2 to produce reference beam 6, and said s-polarized probing pulses 4 with said p-polarized probing beam 5 to produce probing beam 7;

splitting said reference beam 6 into s-polarized reference beam 8 and p-polarized reference beam 9, and said probing beam 7 into s-polarized probing beam10 and p-polarized probing beam 11;

pointing said s-polarized reference beam 8 and s-polarized probing beam 10 to photodetector (channel) 1, and said p-polarized reference beam 9 and p-polarized probing beam 11 to photodetector (channel) 2.

measuring electrical signals S_{ref}, P_{ref}, S_{prob}, P_{ref}, corresponding to the detection of s-polarized reference beam 8, p-polarized reference beam 9, s-polarized probing beam 10, and p-polarized probing beam 11, respectively.

making a conclusion about the presence of said target substance in said target volume by comparing the $\frac{S_{ref}}{P_{ref}}$ and $\frac{S_{prob}}{P_{prob}}$ ratios .

23. A method according to Claim 22, wherein said merging of said beam 1 and said beam 2 is provided with polarizer 2.

24. A method according to Claims 22, 23, wherein said reference beam 1 and said probing beam 3 are transmitted through said polarizer 1 and said polarizer 2, and are further delivered to Faraday rotator 3.

25. A method according to Claims 22, 23, wherein said reference beam 4 and said probing beam 5 after passing said polarizer 1 are further reflected by two mirrors and said polarizer 2, and further delivered to said Faraday rotator 3.

26. A method according to Claims 22, 23, 24, 25 wherein after passing said polarizer 2, said reference beams 1,2 and said probing beams 4,5 are transmitted through Faraday rotator 3, a tilted dichroic mirror, and expanding telescope, and are further focused by said objective into said target volume.

27. A method according to Claim 22, wherein said beam 3 is reflected from said dichroic mirror and thus sent coaxially with said beams 1,2,4,5 to said objective.

28. A method according to Claim 25, wherein said two mirrors form an optical delay to provide the delivery of said reference beam 1 to said target before the delivery of said reference beam 2, and the delivery of said probing beam 4 to said target before delivering said probing pulses 5.

29. A method according to Claims 22, 23, 24, 25, 26, 27, 28, wherein an aperture is placed between said polarizer P2 and Faraday rotator 3 to select the lowest spatial mode of said backscattered reference beams 1,2 and said probing beams 4,5.

30. A method according to Claims 22, 23, wherein instead of laser 1 intended for the generation of said linear polarized beam, a split-off portion of said beam 3 is converted using optical means into a beam with shifted wavelength, which is further delivered to polarizer P1.

31. A method according to Claims 22, 23 wherein the delivery of said s-polarized reference beam 8 and s-polarized probing beam 10 to photodetector (channel) 1, and of said p-polarized reference beam 9 and p-polarized probing beam 11 to photodetector (channel) 2 are provided using a polarizer.

32. A method according to Claim 22, wherein electrical signals from said photodetectors (channels) 1 and 2 are electronically analyzed and result in an electrical signal (which may be recorded and displayed) indicating the presence of the detected substance in the target volume.

33. A device for non-contact detection of low concentration and trace substances, including:

a laser beam source 1;

a laser beam source 2;

a first polarizer 1;

a second polarizer 2;

an objective lens;

a first photodiode 1, and

a second photodiode 2,

wherein, a first polarized laser pulsed beam emitted by the laser beam source 1 is split into a beam 1 and a beam 2 with s – and p – polarization, respectively by the first polarizer 1, beam 1 and beam 2 delivered to the second polarizer 2, second polarizer 2 merging beam 1 and beam 2 from the point of merging to the focusing objective lens, a pumping laser beam 3 emitted by the laser beam source 2 with the wavelength matching the resonance line of the target substance, is delivered to the focusing objective lens, , and

wherein a reference pulse 1 with p – polarization and a reference pulse 2 with s – polarization are delivered to objective lens before the delivery of the pumping pulse 3 to the objective lens within probing events; pumping pulse 3 of the laser source 2 is delivered to the objective lens after the delivery of the reference pulse 1 and the reference pulse 2 within probing events, and

wherein a probing pulse 4 with p – polarization is delivered to the objective lens before the delivery of pumping pulse 3, and a probing pulse 5 with s – polarization is delivered to the objective lens after the delivery of pumping pulse 3; and

wherein the objective lens pinpoints and focuses the beams, corresponding to the references pulses, the pumping pulses and the probing pulses, such that their waists in the focus of the objective lens in the target region overlap each other, and

wherein the target sends backscattered reference pulses 1 and 2 and the backscattered probing pulses 4 and 5 to the first polarizer 1 where a s – polarized reference pulse 1 is combined with a p – polarized reference pulse 2, originating a reference pulse 6 and a s – polarized probing pulse 4 is combined with a p – polarized probing pulse 5 within probing events originating a probing pulse 7, and

wherein the reference pulse 6 is split into a s – polarized reference pulse 8 and a p – polarized reference pulse 9, and the probing pulse 7 is split into s – polarized probing pulse 10 and p – polarized probing pulse 11, and

wherein the s – polarized reference pulse 8 and the s – polarized probing pulse 10 are sent to the photodiode 1, and the p – polarized reference pulse 9 and the p – polarized probing pulse 11 are sent to the photodiode 2, and the photodiodes 1 and 2 identify the presence of the target substance.

34. A device for non-contact detection of low concentration and trace substances, including:

a laser beam source 1;

a laser beam source 2;

a first polarizer 1;

a second polarizer 2;

an objective lens;

a first photodiode 1, and

a second photodiode 2,

wherein, a first linear polarized beam of a CW laser 3 emitted by the laser beam source 1 is split by the first polarizer 1 into a CW - beam 1 and a CW - beam 2 with s – and p – polarization, respectively; beam 1 and beam 2 delivered to the second polarizer 2, the second polarizer 2 merging beam 1 and beam 2 from the point of merging to the focusing objective lens; a pumping laser beam 3 emitted by the laser beam source 2 with the wavelength matching the resonance line of the target substance, is delivered to the focusing objective lens, and

the CW – beam 1 and the said CW – beam 2 are delivered to the objective lens, the objective lens focusing the CW beam 1, the CW beam 2 and the pumping beam 3 such that their waists in the focus of the objective lens in the target overlap each other, and

wherein the target sends a backscattered CW beam 1 and a backscattered CW beam 2 to the polarizer 1 such that a s – polarized CW beam 1 is combined with a p – polarized CW beam 2, originating a CW beam 4, and

wherein CW beam 4 is split into a s – polarized CW beam 5 and a p – polarized CW beam 6, and

wherein the s – polarized CW beam 5 is sent to photodiode 1, and the p – polarized CW beam 6 is sent to photodiode 2; the photodiodes measuring the waveforms S and P of electrical pulses at outputs of photodiode 1 and photodiode 2, respectively; and identify the presence of the target substance.

FIG. 1

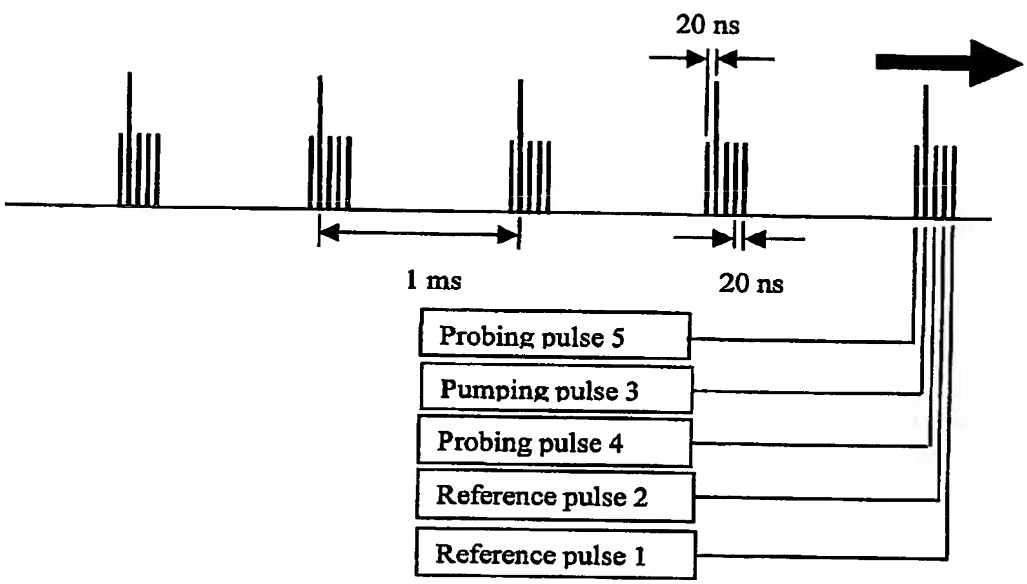

20 ns
1 ms
20 ns
Probing pulse 5
Pumping pulse 3
Probing pulse 4
Reference pulse 2
Reference pulse 1

FIG. 2

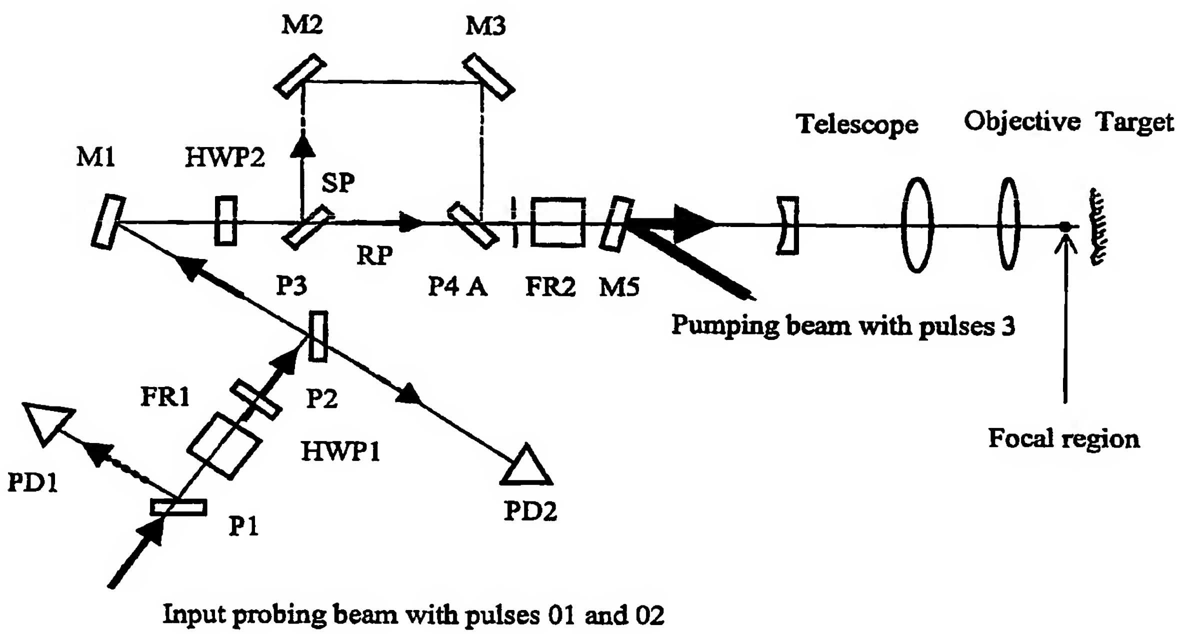
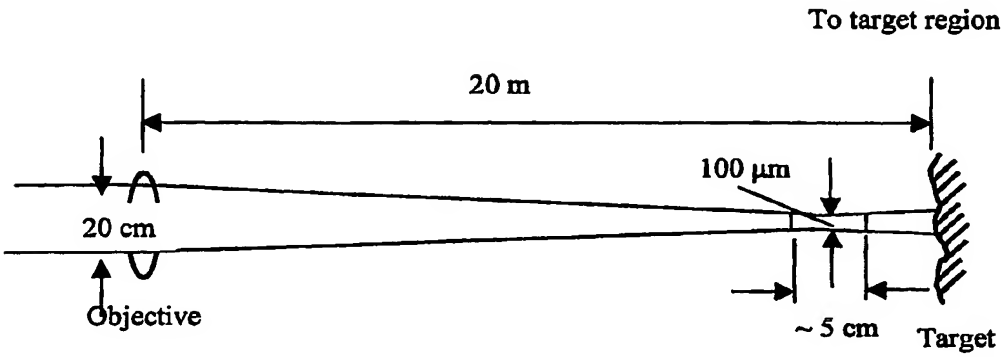

M2
M3
Telescope
Objective
Target
M1
HWP2
SP
RP
P3
P4 A
FR2
M5
Pumping beam with pulses 3
FR1
P2
HWP1
PD1
P1
PD2
Focal region
Input probing beam with pulses 01 and 02

FIG. 3



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